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Three possible cases of cranioclasis indicating obstetric extraction of the fetus in a Spanish rural population of the late 17th and early 18th Centuries

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SUMMARY

Cranioclasis is a technique that was formerly used to extract the fetus during births that were complicated due to different causes. This procedure was usually resorted to once the fetus was confirmed to be dead. This technique was substituted by the caesarean section in the mid-twentieth century. The aim of this study is to analyze osseous lesions observed in the crania of three neonates buried in the period between the end of the 17th century and the beginning of the 18th century in the church-fortress known as *Iglesia Fortaleza de Nuestra Señora de los Ángeles* in Castielfabib, Rincón de Ademuz, province of Valencia, Spain. The instrumental incisions found in the occipital bones of the three neonates, as well as the overlap of their neurocranial bones, are compatible with cranioclasis. The cranial lesions in the three neonate occipital bones discovered in Castielfabib in Ademuz-Valencia, Spain could confirm the practice of cranioclasis in this region of Spain at the end of the 17th century and the beginning of the 18th century.

Key words: Newborn – Occipital bone – Skull fractures – Obstetric labor complication – 17th Century – Spain

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INTRODUCTION

Obstructed labor is a major complication that constitutes a life-threatening situation for both mother and child, as the fetus is unable to pass through the maternal pelvis. This may be due to a number of reasons, such as the mother having suffered from rickets, fetal hydrocephalia or macrosomia, fetal deformities, or some malpresentations (Neilson et al., 2003). In an attempt to save the mother's life after the fetus was confirmed to be dead, various techniques were historically used, such as cranioclasis or basiotripsy, in which the fetal cranium is crushed to facilitate delivery (Lauro, 1888) (Fig. 1).

There is documented evidence from as long as 4000 years ago on the tools and procedures for fetal extraction. Ancient Egyptian bas-reliefs from Kom Ombo temple depicted an array of medical instruments for that purpose (Hönigsberg, 1962). Moreover, Hindu medicine from around 1500 BC used instruments similar to forceps, as in the case of "Śanku", "Mandalágra" and the "Anguli-sástra", used for craniotomy (Bhishagratna, 1911; Mukhopadhyaya, 1913).

Similarly, in Ancient Greece, Soranus of Ephesus (139-98 BC) described the use of different types of hooks to extract dead fetuses by embryotomy (Soranus, 1882; King, 2007). Furthermore, removal of a dead fetus from the mother's womb by cranioclasis is detailed in the Hippocratic Corpus (Schäfer, 1996; King, 2007).

In the Middle Ages, there is evidence of vaginal

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extraction of the dead fetus by fetal cranial crushing when the delivery was obstructed. This was the last option that was resorted to when other methods failed and fetal death was confirmed (Schäfer, 1996). In the Early Middle Ages, fetal extraction was recorded in Byzantine medical treatises, like Aëtius of Amida (505-575) and Paulus Aegineta (625-690) (King, 2007), as well as Arab physicians like Abulcasis (936-1013) and Avicena (980-1037) (Aëtius d'Amide, 1901; Schäfer, 1996). Moreover, throughout the High and Late Middle Ages, authors like Arnau de Vilanova (1238-1311), Guy de Chauliac (1300-1368), Antonio Benivienio (1443-1502) and Alessandro Benedetti (1450-1512) described this type of procedure (Schäfer, 1996).

In the 16th century, Jakob Rüff (1500-1558) illustrated the variety of instruments used to extract the dead fetus when a delivery was obstructed in his book *The Expert Midwife* (Rüff, 1600; Keller et al., 2006). Among other obstetric operations, Ambroise Paré (1510-1590) described the use of hooks to extract pieces of the dead fetus that failed to be delivered spontaneously (Paré, 1550; Stofft, 1998).

The technology of delivery in obstructed labors remained primitive throughout the 17th century and until the mid-eighteenth century. Prolonged obstructed labors led to the death of the child, and posed a great risk for the mother, whose life could only be saved by surgical intervention and then by extracting the dead child with hooks (Wilson, 1992; Worth-Stylianou, 2006). William Smellie (1697-1763) left detailed accounts of the various instrumental options available, like the crotchet, a sharp hook used for the craniotomy (Smellie and Hamilton, 1793). In that period, the use of alternative techniques started to be developed.

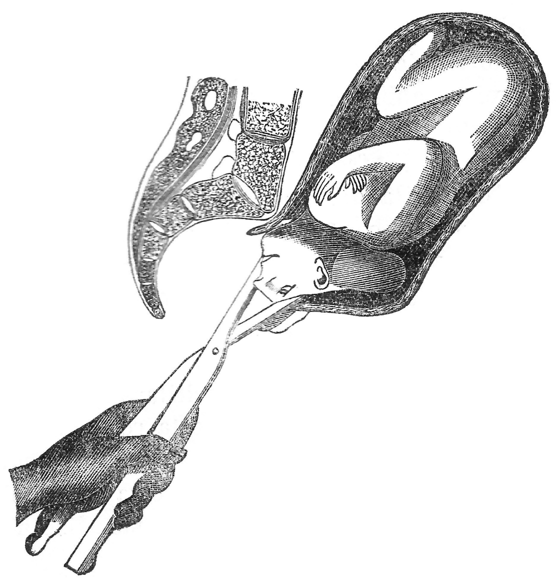

Fig. 1. Illustration dating from 1888 showing a cranioclasis procedure (Lauro, 1888).

In this context, Peter Chamberlen (1560-1631) designed a pair of forceps with separated and adjustable segments (Wilson, 1995; Dunn, 1999). Jean Palfyn (1650-1730) invented a device in 1720 with non-fenestrated spoon-shaped pincers, called “hands of iron”, which are considered the precursors of the obstetric spatulas (De Rom, 1950; Wilson, 1995).

In the 18th century, the development of new methods allowed saving the lives of both mother and child in many difficult labors. One of those methods was the symphysiotomy, a surgical procedure in which the cartilage of the pubic symphysis is divided to widen the pelvis allowing childbirth when there is a mechanical problem. This procedure was used until 1990s (Viglione, 2013). But the revolution in obstetric methods took place in the early 18th century, when the use of forceps for delivering difficult births gradually became more widely available (Wilson, 1992).

Subsequently, in the 18th and 19th centuries, various models of forceps and basiotribes appeared, of which Tarnier-Bar’s basiotribe was noteworthy along with other instruments, such as Zweifel’s cephalocranioclast, Febling’s *cephalotriphelktor*, Döderlein’s *cephalotriptor*, Auvard’s combined cephalo-embryotome, Braun’s obstetric extraction hook, Blot’s dagger and Siebold and Pinard’s scissors (Cabero- Roura and Saldívar-Rodríguez, 2009). In complicated births in which the use of forceps did not provide a solution, surgical embryotomy was the usual practice, either by decapitation of the fetus or basiotripsy. It was not until the second half of the 20th century that these practices gave way to the caesarean section (Bottoms et al., 1980).

In spite of the abundance of historical documents that confirm these obstetric practices, there is insufficient paleopathological information based on the direct analysis of fetal cranial lesions consistent with cranioclasis. That is why this study analyzes the possible use of these kinds of procedures by examining bone lesions in the crania of neonates from a sample of a rural Spanish population from the end of the 17th century and the beginning of the 18th century.

MATERIALS AND METHODS

This study was approved by the Ethics Committee for Research in Humans of the University of Valencia. In addition, the proper permit was obtained from the local authorities of the "Consellería de Cultura de la Comunidad Valenciana" (Regional Ministry of Culture of the Valencian Community) to carry out the anthropological study on the specimens found in the fortress-church *Nuestra Señora de los Ángeles* in Castielfabib (Rincón de Ademuz, Valencia, Spain).

The specimens were discovered between 1999 and 2005 during the restoration work on the fortress-church *Nuestra Señora de los Ángeles* in Castielfabib (Rincón de Ademuz, Valencia, Spain). The fortress-church was initially constructed as a castle in the 12th century upon the remains of an earlier Roman, and later Arab, fortress. Subsequently, during the 13th and 14th centuries, one of the defensive towers was enlarged and converted into a palace; later still, its upper level was reconverted into what is the present-day church (López-González and García-Valldecabres, 2012). The specimens discovered in the interior of the church date from late 17th century to early 18th century, as has been revealed by the objects and clothing found in the tombs, as well as by the historical context.

All of the specimens found were first labelled according to their stratigraphic unit status at the fortress-church *Nuestra Señora de los Ángeles* in Castielfabib, and then they were taken to the Anthropometry and Paleopathology Laboratory of the Department of Anatomy and Human Embryology of the University of Valencia to be studied.

The scientific methodology applied followed the recommendations of the International Paleopathology Association (Rose et al., 1991) and those of the *Asociación Española de Antropología y Odontología Forense* (Spanish Forensic Anthropology and Odontology Association) (Serrulla, 2013).

The specimens were relatively clean as their inhumation had taken place in cavities of walls and under the stone floor of the church and had no organic remains or sediments adhered to them (except for a few specimens with mummified soft tissues adhered to the bones). Nonetheless, the bones were cleaned for their initial study with soft-bristle brushes under a constant low-pressure water jet (Serrulla, 2013) and then placed in an ultrasound bath with double distilled water (Villalaín-Blanco and Polo-Cerdá, 2000). After each osseous piece was cleaned, it was dried in a drying device by using absorbent paper and drying trays with racks subject to mechanical ventilation in a dryer at room temperature; the bones were protected from direct sunlight (Villalaín-Blanco and Polo-Cerdá, 2000). No reconstruction work was necessary after drying. The partially mummified specimens were only cleaned with soft-bristle brushes.

A total of 331 individuals were exhumed, of which 177 were adults (97 men and 80 women), 44 were neonates and 110 were infants.

The occipital bones analyzed in this study belonged to three neonates. Their skeletons were partially complete, and one of them partially mummified. It was not necessary to calculate the minimum number of individuals as one skeleton was found in an individual tomb, located in the wall of the church, while the other two were exhumed from collective tombs where the skeletons were resting in an individual fashion and were neither mixed nor overlapping with other skeletal remains. Although sex determination in neonates is fairly unreliable (Lewis, 2007), the greater sciatic notch of the pelvis was analyzed according to Boucher (1955) to estimate the possible sex of the neonates (Schutkowski, 1993). This procedure was not required in the case of the neonate partially mummified because its remains allowed accurate determination of sex.

Age was established according to the measurements of the diaphysis of humeri, radial bones, femora and tibiae. Considering that our sample population is of Spanish origin, we would apply the Iberian-population-based functions from Rissech et al. (2013) to estimate the age of sub-adult skeletons. However, Rissech's method is applicable only to skeletons older than 1 year old. Therefore, we were unable to apply Rissech's method because our 3 cases were younger than 1 year-old. The application of nomograms from Hoffman (1979) to estimate the age in specimens 2 month-old and older was unsuccessful because the dyaphiseal lengths of our specimens were shorter than the minimum length required for those nomograms. Therefore, we considered that our specimens were younger than 2 month-old. Finally, we used the method described by Olivier and Pineau (1960) to estimate the fetal age (applicable between 4.25 and 10 lunar months). Nevertheless, these methods to estimate age are based in populations from the 20th century, which could limit its precision for populations previous to the 20th century. For that reason, in addition to Olivier and Pineau's method, age was also estimated from the membranous gaps in the frontal bones and fontanelles and other typical features of the bones of a neonate (Schaefer et al., 2009; Baker et al., 2010).

The osseous lesions observed in the crania of the neonates were analyzed at both macroscopic and microscopic levels. The microscopic evaluation was performed with the aid of a digital USB microscope, model XCSOURCE® USB 20X-500X. The microscopic evaluation could only be performed in the two cases in which the occipital bone was detached, but not in the case in which the set of cranial bones overlapped due to mummification, since the process would have damaged the specimen.

RESULTS

Among the specimens exhumed (N=331), three cases of neonates with similar skull fractures in the occipital bones were found. The three specimens were aged 37-40 weeks-old.

Case 1 (Fig. 2) was a possible female neonate who was partially mummified and presented all of the bones of the neurocranium; the rest of the skeleton was almost complete, except for most of the phalanges of the hands and feet, the

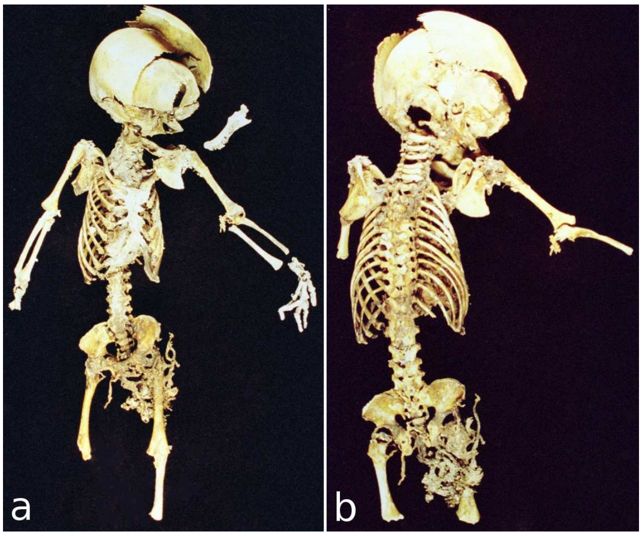

Fig. 2. Case 1, a partially mummified neonate: **(a)** frontal view, **(b)** rear view.

right hand, the right leg and both feet. Cases 2 and 3 were partial skeletons of possible male neonates of whom only the occipital bones, fragments of the rest of the neurocranium, some long bones, pelvis, part of the spine and fragments of ribs were present in each.

Incised lesions can be observed in the three occipitals at the level of the sagittal suture and, laterally, at the site of the two Mendosa sutures. The lesions are all similar: linear and centripetal, clean-cut in a wedge shape and with no signs of osseous regeneration. Fig. 3 shows a macroscopic view of these lesions. In case 1 the lesion was viewed at the level of the sagittal suture. In case 2 the lesions were observed at the level of the sagittal suture and the left Mendosa suture. In case 3 the lesion is only viewed at the level of the sagittal suture and the left Mendosa suture, since the occipital presented a loss of osseous matter in the right Asterion.

Fig. 4 shows an enlarged view of the lesions at the level of the sutures of cases 2 and 3. The edges and endings of the sutures are smooth and wedge-shaped. The lesion goes beyond the suture, thereby only affecting the outer table of the bone.

Interestingly, in case 1, where all of the bones of the neurocranium were present, the frontal and parietal bones did not present incised lesions, even though there was evidence of an excessive overlap of the bones. Moreover, a significant facial depression was observed with destruction of the viscerocranium (Fig. 2).

Furthermore, other fissures were observed in the three occipitals which, in contrast to those described above, had irregular or rounded edges, varying lengths and an asymmetrical or irregular distribution.

It is also striking that in the long bones of the partially mummified skeleton in case 1, multiple erosive lesions appear at the ends of the bones in a parallel pattern which look like the marks of the teeth of a saw, as well as small fissures located only in the periosteum.

DISCUSSION

Similar incised lesions can be seen in the three occipital bones: the bone edges are rectilinear and run in a centripetal direction and they only affect the outer table of the occipital, like a

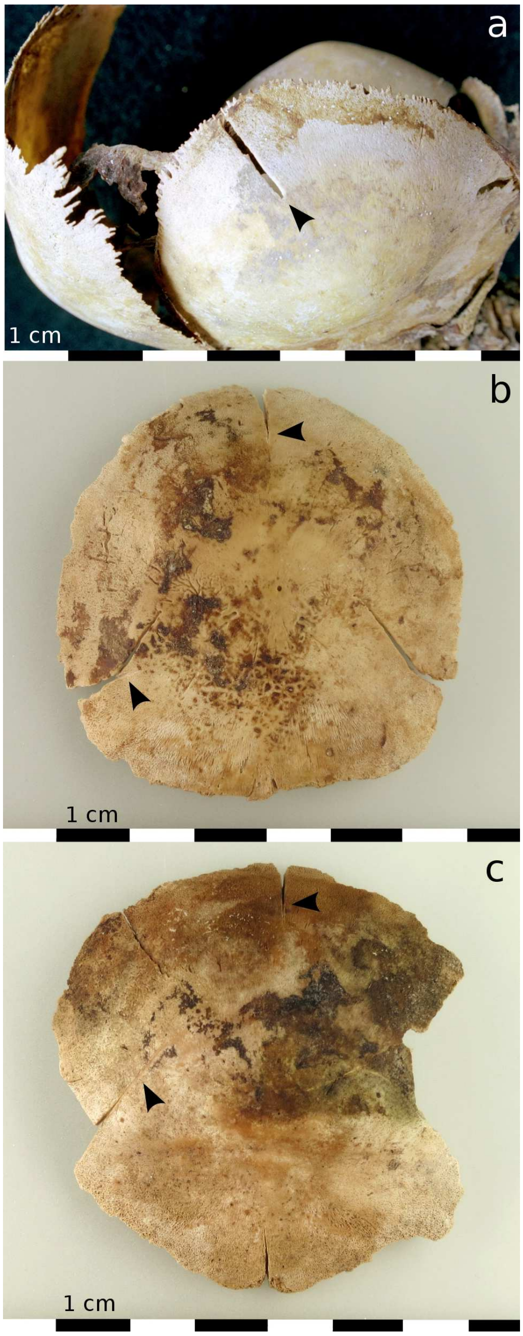

Fig. 3. Macroscopic view of the incised lesions in the occipital bone. **(a)** Case 1: At the level of the sagittal suture. **(b)** Case 2: At the level of the sagittal suture and the left Mendosa suture. **(c)** Case 3: At the level of the sagittal suture and the left Mendosa suture. Arrow heads: incised lesions.

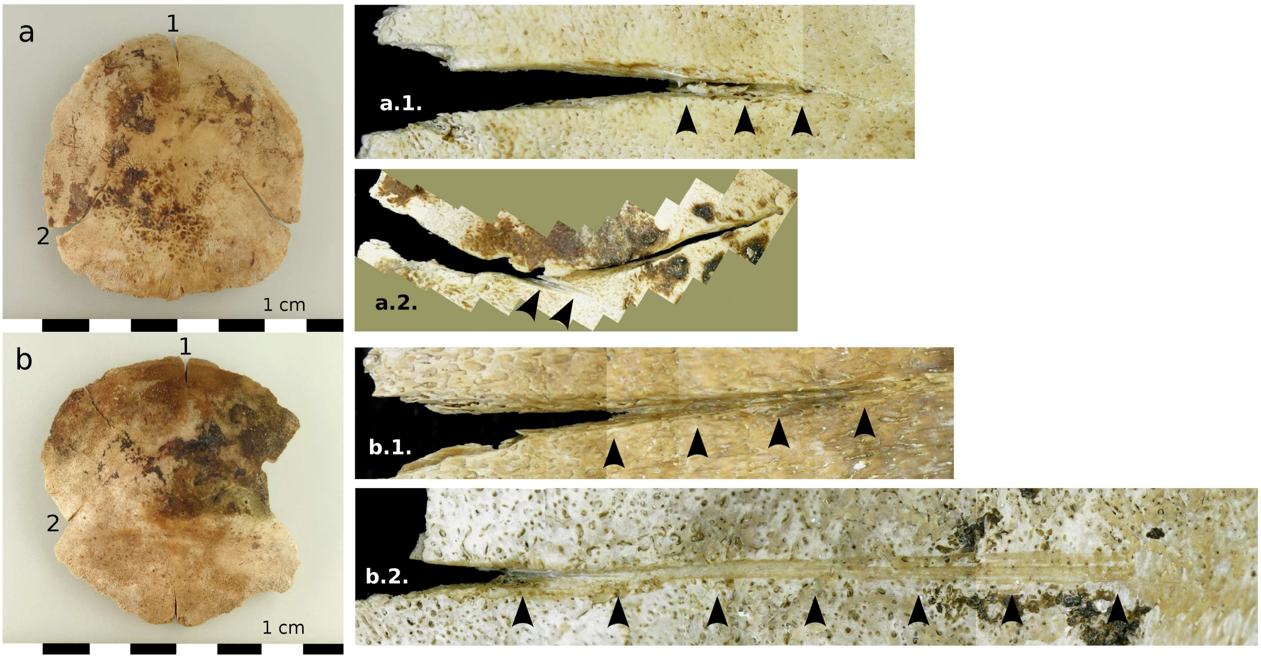

Fig. 4. Enlarged view of the incised lesions in the occipital bone. **a**) Case 2: a.1) Incised lesion at the level of the sagittal suture; a.2) Incised lesion at the level of the left Mendosa suture; **b**) Case 3: b.1) Incised lesion at the level of the sagittal suture; b.2) Incised lesion at the level of the left Mendosa suture. Arrow heads: incised lesions.

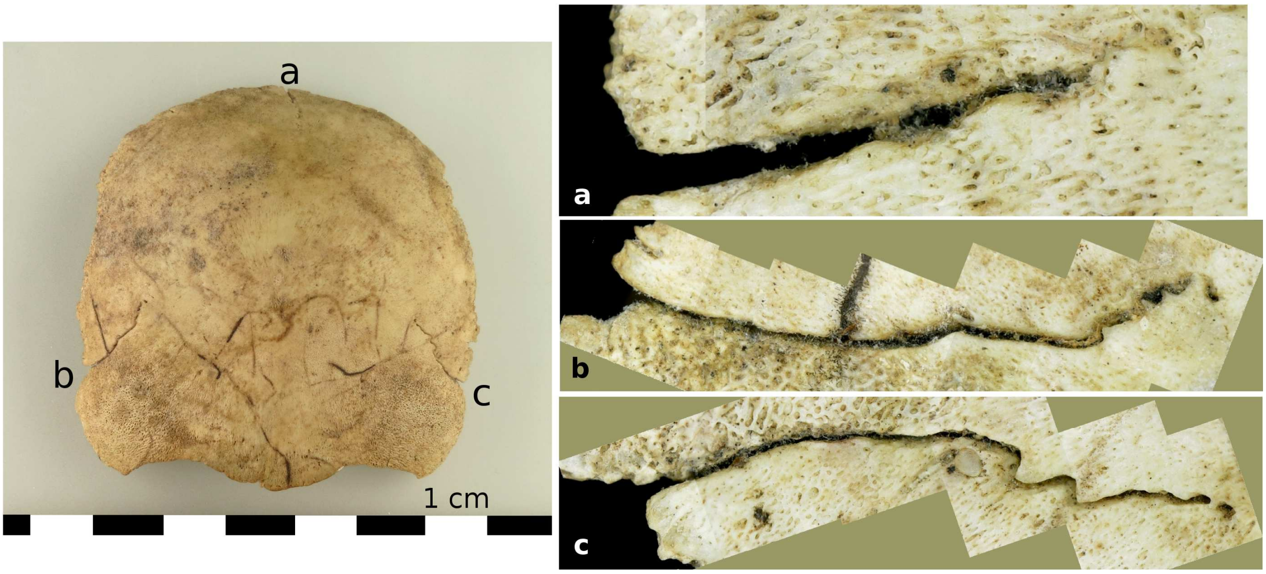

Fig. 5. Enlarged view of the sagittal suture and the Mendosa sutures in a normal neonate occipital bone; **a**) Sagittal suture; **b**) Left Mendosa suture; **c**) Right Mendosa suture.

superficial cut.

The location of these incisive lesions is at the sagittal suture and, laterally, at the site of the two Mendosa sutures normally present in neonate occipitals (Schaefer et al., 2009; Baker et al., 2010). However, the lesions differ morphologically from the sutures, which have rounded, curved edges as opposed to the straight and wedge-shaped lesions seen in these occipitals. This can be compared in Fig. 5 which shows the morphology of these sutures in a normal neonatal occipital bone. Moreover, the incised lesions only affect the outer table of the occipital in some sections. This could mean that they were incised lesions on top of the sutures.

The similar characteristics of the lesions seem to indicate that a common mechanism was used.

One of the possible causes of these lesions could have been the accidental action of archaeological instruments used during the exhumation. This post-mortem possibility explaining the lesions was discarded, however, as the three neonates were protected inside their respective coffins and also because, unlike the linear incisive lesions observed in this study, the taphonomic fractures show different morphological characteristics, such as a greater transversality with rough, irregular edges (Etxeberría and Carnicero, 1998). For this reason, it was considered that the lesions were perimortem.

The linear, wedge-shaped lesions suggest the shearing effect of a cutting mechanism (Chiarri-Rodrigo, 2001). This may indicate that it was a case of neonate infanticide, but the presence of several simultaneous lesions in the occipital bone suggests that the cause was more likely to have been an instrument for crushing and extracting the cranium during delivery. In support of the latter hypothesis of practicing cranioclasis is the fact that in case 1, in which the neurocranium was complete, there was an overlap of the frontal, parietal and occipital bones as well as facial bone flattening. In this regard, the observed overlapping of lesions and sutures on the three cases could be due to the use of mastoid fontanelles and occipital fontanelle as possible reference points for hooks or tools used for the cranioclases procedure. Since the most common form of cephalic presentation is the vertex presentation, where the occiput is the leading part that first enters the birth canal (Darbois, 1999), both the occipital fontanelle and the two mastoid fontanelles could lead the insertion of hooks on the softer tissue and help to keep the head flexed through the cervix.

Additionally, according to the methodology used to determine the specimen age, the three specimens were 37-42 weeks-old. This age would be compatible with birth time and a potential obstructed labor needing cranioclasis. Despite the fact that this method to estimate age is based on today's population (Olivier and Pineau, 1960; Hoffman, 1979) instead of 17th and 18th century populations, the presence of Mendosa sutures supports the estimated specimens' age.

On the other hand, the remaining fissures found in the occipitals of the neonates, with irregular, curved edges, could be explained by external pressure and other damages caused by taphonomic factors (Villalaín-Blanco and Polo-Cerdá, 2000). They could also have been caused by postmortem animal scavenging. For example, in case 1, where the long bones showed lesions at the ends similar in surface, indicating that rodents gnawed them (Burns, 2008).

Furthermore, it should be taken into account that the discovery of these neonates in the interior of a chapel in a Catholic church strongly suggest that they were baptized. Otherwise, the neonates who died before receiving this sacrament were buried outside of what was deemed a holy place. This suggests that the three neonates were born alive (Murphy and Donnelly, 2010). However this fact does not prove that the neonate was born alive since emergency baptism "sub conditione" was practiced in Spain in the 17th and 18th centuries, without the need for the neonate to show signs of life even during the intrauterine passage. Furthermore, in urgent cases the baptism could be administrated *in utero* in recently deceased children in order to save the neonate's soul regardless of the final outcome of the birth (Echarri, 1778; Benedicto XIV, 1803; Miguélez-Domínguez et al., 1952; Carmona-González and Sáiz-Puente, 2009; Séguy and Signoli, 2008).

In addition, the fact that 2 out the 3 specimens analyzed were possibly males could be a result of a higher fetal death risk among males compared to females from environmental stressors (Catalano et al., 2005). However, this sample size (3 specimens) is too small to draw any conclusion on that regard.

Nevertheless, even though the practice of cranioclasis in the 17th and 18th centuries has been reported (Smellie and Hamilton, 1793; De Rom, 1950; Wilson, 1992; Wilson, 1995; Dunn, 1999; Worth-Stylianou, 2006; Cabero-Roura and Saldívar-Rodríguez, 2009), we have not been able to establish the specific instruments that were used to cause the lesions to the neonate occipitals, because the lesions we observed in this study.

Conclusions

The cranial damage observed in the neonates buried inside the church called *Iglesia de Nuestra Señora de los Ángeles* in Castielfabib are compatible with the practice of cranioclasis, therefore this obstetric technique could have been applied in the area of Rincón de Ademuz, Valencia, Spain in the late 17th and early 18th centuries.

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